

Závorka, L., Koeck, B., Killen, S. S. and Kainz, M. J. (2019) Aquatic predators influence flux of essential micronutrients. *Trends in Ecology and Evolution*, 34(10), pp. 880-881. (doi: [10.1016/j.tree.2019.06.005](https://doi.org/10.1016/j.tree.2019.06.005)).

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Deposited on: 26 July 2019

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Aquatic predators influence flux of essential micronutrients

Libor Závorka^{1*}, Barbara Koeck¹, Shaun S. Killen¹, Martin J. Kainz²

¹*Institute of Biodiversity, Animal Health & Comparative Medicine, Graham Kerr Building, College of Medical, Veterinary & Life Sciences, University of Glasgow, Glasgow G12 8QQ, UK*

²*WasserCluster Lunz–Inter-university Centre for Aquatic Ecosystem Research, A-3293, Lunz am See, Austria*

*Corresponding author: liborzavorka@email.cz

Twitter handles: @shaunkillen @Barbara_Koeck. @kainz_lab

A recent review summarized the key position occupied by aquatic predators in ecosystems [1] and their importance for the adaptive management of aquatic ecosystem functions and services. This review highlighted that more research is needed to understand the mechanisms and extent to which aquatic predators influence micronutrient and trace element fluxes within ecosystems. While this field deserves more attention, a large body of evidence already exists to suggest that aquatic predators play a crucial role for the flux of essential micronutrients not only within marine and freshwater food webs, but also as a vital source of dietary micronutrients for terrestrial animals including humans [2,3,4]. We suggest that extending the social and ecological framework proposed by Hammerschlag *et al.* [1] to the known effects of aquatic predators on flux of essential micronutrients can improve the management of aquatic predators and aquatic ecosystem functioning and services.

While the transfer of dietary energy across trophic levels is usually defined in terms of macronutrients (*e.g.* C, N, and P), it is increasingly recognized that the transfer of trophic energy is limited by the availability of essential dietary micronutrients [5]. For example, bioactive essential fatty acids (EFAs), such as docosahexaenoic acid (DHA, 22:6 ω 3) and

eicosapentaenoic acid (EPA, 20:5 ω 3) are micronutrients necessary for the functioning of many consumers [3,4] and have been shown to play an especially important role in the development of neural tissues of animals [2,4]. Most animals, including humans, have a limited capacity to synthesize these EFAs *de novo* in quantities required for their physiological demand, so these micronutrients must be supplied through the diet [4,6]. EFAs are produced by some marine and freshwater algae, *e.g.* diatoms [5,6]. However, aquatic predators bioaccumulate these micronutrients in their tissues at disproportionally higher quantities than consumers at lower trophic levels [6]. Consequently, carcasses and also eggs of aquatic predators are important sources of these essential micronutrients for consumers, generating fluxes of EFA within and between marine, freshwater and terrestrial food webs [3]. For instance, in marine food webs the exceptionally high biomass of eggs produced during spawning by the predatory twin-spot red snapper *Lutjanus bohar* is utilized by a range of aquatic consumers and facilitates the counter-gradient transfer of energy and micronutrients from higher to lower trophic levels [7]. In coastal British Columbia, bears and wolves consume lipid rich heads of spawning Pacific salmon *Oncorhynchus spp.* during seasonal salmon runs, behaviour that can be explained by targeting EFAs in the tissues of the aquatic predators [8]. In humans, the consumption of EFA-rich seabird nestlings and eggs has been identified as a key element in the evolution of neural tissue and cognitive capacity of early *Homo sapiens* [2]. Therefore, decline or increase of abundance of aquatic predators can affect the flux of EFAs throughout the food webs.

The key role of EFAs for the development of neural tissues of animals [2,6] also implies that cognition and behaviour of aquatic predators depend on EFAs supply to their neural tissues. Hindered cognition of aquatic predators caused by EFAs deficiency can reduce their capacity to forage across macrohabitats and flexibly utilize different prey types, which can decrease the stability of aquatic food webs [9]. Several factors directly related to anthropogenic effects on aquatic ecosystems can reduce the supply of EFAs for neural tissues of aquatic predators. For

instance, overfishing and climate regime shifts have been shown to change EFA composition of prey fish in marine ecosystems [10]. In addition, evidence suggests that rising water temperature and fisheries-induced selection can cause changes in physiological performance of some aquatic predators [6,11], which might alter their capacity to accumulate and synthesize EFAs. Therefore, studying variability of EFA profiles of aquatic predators might improve predictions about how they respond to anthropogenic environmental changes and help understand interactions and feedbacks between aquatic predators and ecosystems.

Aquatic predators are a significant component of modern human diet, particularly in communities historically dependent on the harvest of marine and freshwater fish and mammals [1]. More importantly, aquatic predators are a major source of dietary EFAs for humans across the globe [3,4,12]. The requirement of dietary EFAs for human health calls for adaptive management balancing conservation of aquatic predators and supply of essential micronutrients for a growing human population [4]. Development of alternative production of EFAs for human consumers is therefore critical to ease the pressure on wild populations of aquatic predators. Production of EFAs based on animals at lower trophic levels or primary producers [12] and bio-inspiration of production technologies by the high capacity of some aquatic predators to accumulate and synthesize these micronutrients may be a promising direction in adaptive management of aquatic predators and ecosystems.

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